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REFURBISHMENT OF DAMAGED TOOLS USING THE COMBINATION OF GTAW AND LASER BEAM WELDING

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This paper presents the use of two welding processes for the refurbishment of damaged industrial tools. In the first part the problem is presented followed by the comparison of GTAW and laser welding in terms of repair welding of damaged tools. The macrosections of the welds show the difference between both welding processes in repairing of damaged tools. At the conclusion the main findings are presented. In many cases it is useful to use both welding processes in order to achieve better weld quality and to make welding more economical. The order of the technology used depends on the tool material, the use of the tool and the tool damage.

Key words: laser welding, GTAW, repair welding, tool, undercut

INTRODUCTION

Industrial tools are usually made of metal materials. Typical failures occurring on the tool surfaces are wear, chip and surface cracks. A decision for making a new tool or refurbishment of worn tool depends on costs of the new tool, the costs of refurbishment and expected tool life of either selection. If refurbishment of tool is made, the personal and the equipment of the maintenance shop has the high influence on the quality of repair and consequently on tool life time. It is necessary to have the base knowledge about welding metallurgy, material properties and practical experiences with repair welding of tools [1-5].

PROBLEM DESCRIPTION

Tools for high pressure die casting of non-ferrous alloys, injection moulding, forming and cutting are usually refurbished due to the high costs of the new one tools. The preparation of the repair welding technology is normally complex and care must be taken during preheating, welding and post weld heat treatment [6-8]. Welding is also the only technology suitable for refurbishment of damaged tools. In order to achieve a sound welds following factors must be considered; the choice of proper filler material, welding procedure, heat treatment, and skilled personal [9-15]. Arc welding is widely used for tool refurbishment. Gas tungsten arc welding (GTAW), gas metal arc welding (GMAW) or plasma arc welding (PAW) can be used. Normally GTAW is used due to its flexibility, accuracy and energy concentration. Modern power sources allow the welding with low current and narrow arc which is useful for maintenance work.

Laser beam welding (LBW) is the newer procedure used for refurbishment [16-20]. It is an accurate process in which desired shape of the weld can be made. After the successful repair the machining of the weld is minimal due to the controlled deposition rate of the filler material. The second advantage of LBW is the limited influence on base material beneath the weld bead deposited weld quality. Low productivity and high equipment costs are the disadvantages of the LBW. Filler materials for LBW are expensive due to the high manufacturing costs of wire drawing [21]. For quality tool refurbishment a skilled and responsible personnel is of highest importance.

LBW can not only compensate arc welding processes but can be used to improve the quality of the weld made by arc welding processes and the combination of both technologies can achieve the advantages of GTAW and LBW.

Monochromatic, coherent light of the laser beam is used as a heat source at LBW. During GTAW the electrical energy is converted into heat of electrical arc [22]. Figure 1 shows some differences between GTAW and LBW [23].

Figure 1a and 1b show the energy distribution for GTAW and LBW. The laser beam (LB) is concentrated with lenses and mirrors to get the beam energy density of 1010 W/m^2, which is for a factor of 103 higher compared with GTAW. Due to the flow of the electrical current the electromagnetic field is formed around the arc. This field is homogeneous on the level plate. If the arc burns inside of the narrow gap this field becomes inhomogeneous as shown in the Figure 1c.

The observed weld undercuts are different for the mentioned processes. Weld undercuts are surface de-

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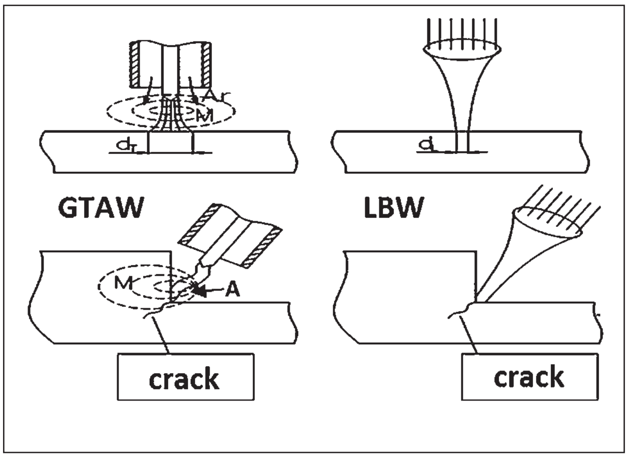

Figure 1 Schematic presentation of LBW and GTAW; d_T, d_L - the diameter of the energy flow, *M* - the expansion of the electromagnetic field, *A* - point of concentrated magnetic fields and welding on the surface a) GTAW and b) LBW and welding of corner crack c) GTAW and d) LBW

fects which can be observed on the edges of the deposited welds. These defects appear due to the shrinkage of the weld metal during solidification of the weld. During GTAW more material melts around the welding arc and the plastic deformation of the material occurs. During solidification it is impossible to get the original state. Weld undercuts that appear during welding are not acceptable at tool refurbishment. During LBW the amount of melted material is much lower leading to the very limited formation of the weld undercuts.

Figure 2, shows two weld macrosections made on the plate edge. Figure 2a shows the weld made using LBW and Figure 2b weld made using GTAW. Almost no undercuts are present at LBW and the heat affected zone (HAZ) is very narrow. Figure 2b shows that the HAZ of the GTAW weld is wider as its height. This weld was made using the filler wire with diameter of 0,8 mm, arc current 11 A and arc voltage 12 V. Argon at 8 l/min was used as a shielding gas. In addition, with the LBW it is much easier to create the desired shape of the weld and hence the post weld machining is minimised.

Since the equipment costs of LBW are high, it is normally used just for those refurbishments where other processes are less flexible.

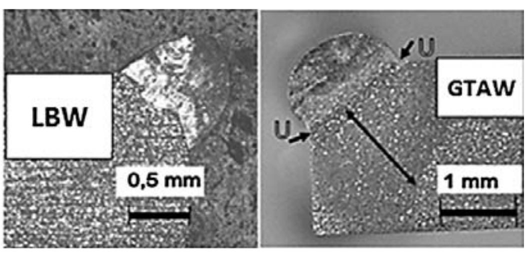

Figure 2 Macrosections of welds made using LBW (left) and with the GTAW process (right): T- width of HAZ, U – weld undercuts

PRACTICAL EXAMPLES

Normally GTAW is used as the initial repair welding procedure followed by LBW. The correct choice of welding process depends on defects type, type of the tool and tool materials and requirements that have to be achieved after repair welding. Figure 3 shows one weld done using LBW on the edge of tool surface. The letter "S" presents the worn out area. The letter "P" presents highly polished surfaces at which it is necessary to avoid the degradation of the surface properties like hardness and waviness.

If only GTAW would be used as a repair welding process both polished surfaces would oxidise and the weld undercuts would form similar as on the Figure 2. In this case the refurbishment would be unsuccessful. Laser welds at the edges of the worn out surfaces solve the problem of repair welding quality (Figure 3a and 3b).

Figure 3a shows the magnification of a macro specimen with the laser welds at the edges of the plate surface. It is shown that the weld has no undercuts with negligible narrow heat affected zone. After deposition of laser welds at the edges of the surface, GTAW can be used to fill the worn surface with the filler material. According to the presented welding procedure the initial cage was made using LBW for the GTAW. Here care

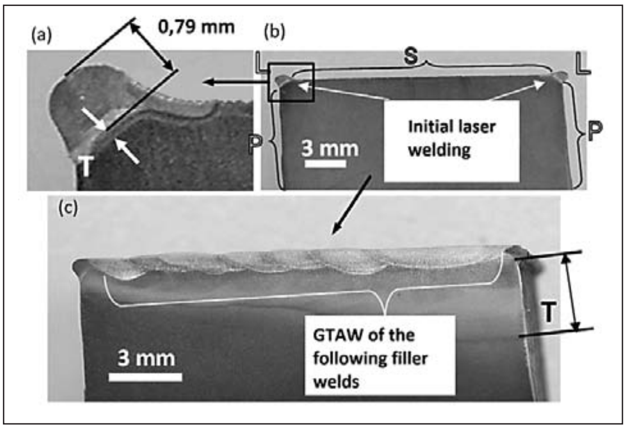

Figure 3 Refurbishment of worn out surface (S) on die casting die with a) and b) LBW and filling of the surface using GTAW. a) weld made by laser, b) a macro specimen made of two laser weld (L), c) macro specimen of a completely remanufactured surface (laser and GTAW), T – HAZ, L - LBW, P - highly polished surface

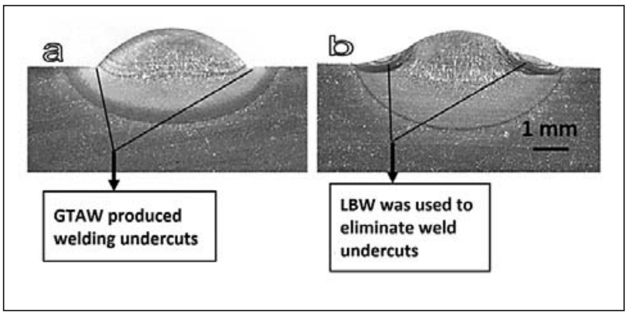

Figure 4 Combination of a) GTAW and b) LBW for elimination of weld undercuts

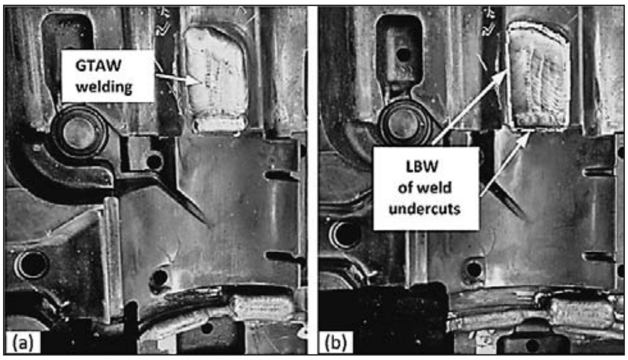

Figure 5 High pressure die casting die, a) GTAW of due surface and b) LBW of GTAW weld undercuts

must be taken at following GTAW deposition at which the correct welding parameters must be used in order to get sufficient weld quality.

GTAW weld undercuts are presented on the Figure 4a. The LBW was used to fill and eliminate GTAW weld undercuts (Figure 4b).

Figure 5 shows a complex die casting tool. Weld undercuts due to the shrinking of the molten alloy at GTAW are not accepted on the die surface. The refurbishment of these die was made by initial GTAW (Figure 5). Weld undercuts were eliminated using pulsed Nd:YAG laser (Figure 5b). Undercuts were repaired with a thin welding wire of 0,4 mm in diameter. The wire was cleaned using SiC paper and wiped with acetone in order to reduce the contamination of weld pool with impurities.

CONCLUSIONS

In order to lower the cost and to achieve better quality of the repair welding process it is necessary to combine two welding technologies as described in this paper. Prior to welding appropriate order of welding processes must be chosen in correlation with correct welding parameters and filler material selection. One of the factors influencing the quality of the refurbishment is the use of appropriate filler material. In most cases different filler materials are used for GTAW and LBW for the same repair. Metallurgical processes affect the mechanical and structural properties of solidified weld. Filler material for GTAW is different as for LBW. Weld undercuts that appear due to the shrinking of the molten alloy can be successfully repaired by LBW. Low heat input and concentrated energy enable small amount of melted material during the welding and hence successful elimination of weld undercuts. When refurbishment the highly polished tools for HPDC the elimination of weld undercuts is of great importance. The irregularities on the surface of the die directly reflect on the surface of the final product. The use of GTAW and LBW in combination enables successful refurbishment of industrial tools.

REFERENCES

[1] J. F. Wallace, D. Schwam, Die Casting Engineer, (2000), 50-58.
[2] S. Thompson, Handbook of mold, tool and die repair welding, William Andrew Publishing, (1999), 22-25.
[3] N. N., Wrought tool steels, ASM Handbook Vol. 1, ASM International, Materials Park, OH, (1993), 1786-1789.
[4] F. J. Winsor, Welding of low-alloy steels, ASM Handbook, Vol. 6, ASM International, Materials Park, OH, (1993), 1659-1663.
[5] Duley W. W., Laser welding, John Wiley & Sons, Inc., NY, (1999).
[6] S. Thomson, Handbook of mould, tool and die repair welding, Abington Publishing, Cambridge, (1999).
[7] J. Grieger, G. Michel, Schweißen und Schneiden, 65 (2005), 583-585.
[8] C. Dawes, Laser welding, Abington Publishing, Abington, (1992).
[9] http://www.rofin.com/index-fe.htm?start=/english/applications/tool-mold-making/laser-deposit-welding-filler-wire-comparison.php, Available on 14.11.2013.
[10] B. Zorc, A. Nagode, B. Kosec, L. Kosec, Eng fail. anal., 33 (2013), 48-54.
[11] M. Fazarinc, T. Muhič, G. Kuglar, M. Trčelj, Eng fail. anal., 25 (2012), 238-249.
[12] U. Trdan, S. Žagar, J. Grum, J.L. Ocaña, International journal of structural integrity, 2 (2011), 9-21.
[13] Z. Bergant, J. Grum, International Journal of Microstructure and Short names Properties, 8 (2013), 17-26.
[14] J. Tušek, M. Hrženjak, K. Pompe, Jež, M. Mulc, JOM-12, Helsingor, Denmark, (2005).
[15] L. F. Golovko, J. Dyveik, V. I. Oreshnik, The Paton Welding Journal, 12 (2001), 43-46.
[16] K. Vollrath, Herne, Der Praktiker DVS Verlag, 55 (2003), 276-281.
[17] C. Dawes, Laser welding, Abington Publishing, Abington, (1992).
[18] R. Brockmann, Schweißen und Schneiden, 52 (2001), 596 -603.
[19] J. F. Ready, Industrial Applications of Lasers, Academic press, New York, (1997).
[20] W. W. Duley, Laser Welding, John Wiley and Sons Inc., New York, (1998).
[21] J. Brnič., Mater. Manuf. Process. 24 (2009) 7/8, 758-762
[22] K. Vollrath, Der Praktiker, 9 (2003), 276-281.
[23] P. Schreiner, H. M. Urbassek, J. Phys. D, Appl. Phys, 30 (1997) 185-193.

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